Water Balance Assessment of Topographically Closed Highland Lake: *the case of Lake Hashenge, Northern Ethiopia*

Eyasu Yazew[1], [*] Shimbahri Mesfin[2], Girmay GebreSamueal [3] and Samuale Tesfaye[4]

[1]Assistant Professor in Land and Water Development, Mekelle University, Mekelle, Ethiopia
[2]MSc in Tropical Land Resources Management, Mekelle University, Mekelle, Ethiopia
[3]Assistant Professor in Soil and Water Management, Mekelle University, Mekelle, Ethiopia
[4]Lecturer in Land Resources Management, Mekelle University, Mekelle, Ethiopia

Abstract

Hashenge is the only closed and high altitude lake found in Tigray region, northern Ethiopia, can support the economic growth of the region through irrigated agriculture, fish industry and ecotourism farming. However, land degradation and subsequent landuse change is threatening the sustainability and water balance of the lake. Unfortunately, no attempts have been made so far to investigate, quantify and provide information regarding the dynamic water balance of the lake. This research was, therefore, carried out to investigate the temporal variation of the surface area of the lake in the past; develop bathymetric information of the lake; estimate the various water balance components of the lake; and recommend appropriate management strategy. Different methodologies were used to address these objectives. For the water balance analysis, for instance, the change in water level and corresponding volume of the lake was determined over an observation period. Various methods were employed to determine the surface inflow (*direct precipitation, catchment runoff and stream discharge*) and the surface outflow (*evaporation and abstraction*) of the lake over the same time. With the other components known, the net groundwater flow was then estimated from the water balance equation of the lake.

The dry season water balance analysis revealed that direct precipitation and stream flow were the major inflow components contributing 66.7% and 33.3% respectively. On the other hand, most of the outflow was in the form of non-productive loss with evaporation constituting the highest portion (83.55%) followed by net groundwater outflow (16.19%). The water withdrawn for productive purposes including irrigation, livestock and household consumption was only 0.26% of the total. The change in volume of the lake during the observation period was - 4.64 million m^3, indicating larger amount of water going out than that comes in. After constantly decreasing during 1888 – 1994, the lake surface area has shown an increase during the last 15 years. This can be attributed to the integrated watershed management effort during the same period which might have increased the stream discharges and groundwater inflow. The annual water balance analysis, that revealed a surplus inflow of 2.36 million m^3 per year into the lake, seems to corroborate this result. This generally indicates the need to enhance the on-going integrated watershed management. However, since this study is the first of its kind, additional and continued investigation is recommended to improve and verify the current findings.

Key words: Water balance, lake, inflow, outflow, bathymetry, integrated watershed management.

1. INTRODUCTION

Ethiopia is blessed with ample amount of water resources that can be developed and utilized for the wellbeing of the people. However, it is unfortunate that these resources are not yet exploited in proper and sustainable way to meet the increasing demand for food and clean water supply.

Growing population density, uncontrolled water abstraction, deforestation and catchment land use changes are putting more and more pressure on lakes, reservoirs and rivers draining into them (Becht and Harper, 2002 and Ayenew, 2004). For long time, water abstraction from many rift valley lakes and

[*]Correspondence to: Eyasu Yazew, Mekelle University, P.O. Box 231, Mekelle, Ethiopia. E-mail: eyasuet@yahoo.com

tributary rivers preceded without the basic understanding of the complex hydrodynamics and fragile nature of the rift ecosystem. This is particularly the case in the Ethiopian rift where there is ever increasing pumping of water that may lead to negative environmental changes in the future (Ayenew, 1998, 2002 and 2004; Halcrow, 1989 and Makin et al., 1976).

Hashenge is the only closed and high altitude lake in Tigray region situated at about 2,440 m above sea level. As part of the surface water resource, it can support the economic growth of the region through irrigated agriculture, fish industry and ecotourism farming. However, like any part of the region, clearing of natural forests for agriculture, poor grazing and farming systems and topographic features make the Hashenge catchment vulnerable to land degradation. This in turn affects the water balance of the lake. Unfortunately, no attempts have been made so far to investigate, quantify and provide information regarding the dynamic water balance, the temporal relationships between rainfall, evaporation, groundwater flow, stream flow and runoff to the lake. This research was, therefore, carried out to generate quantitative information on water balance components of the lake.

The major objectives of the research were to investigate the temporal variation of the surface area of the lake since 1988; develop bathymetric information of the lake (Lake depth contours); estimate the various water balance components of the lake; and recommend appropriate management strategy for future development activities.

2. METHODS AND MATERIALS

2.1 Description of the Study Area

Lake Hashenge is located in Ofla Wereda, Southern Tigray Administrative Zone, Tigray Regional State, Ethiopia. Geographically, the lake is found between 1,386,000 m – 1,400,000 m N and 550,000 m – 560,000 m E UTM (Figure 1). The average annual rainfall and mean monthly temperature of the study area is 988.7 mm and 15.3 ^{0}C respectively (OWARD, 2010). Figure 2 presents the long term rainfall distribution of the area.

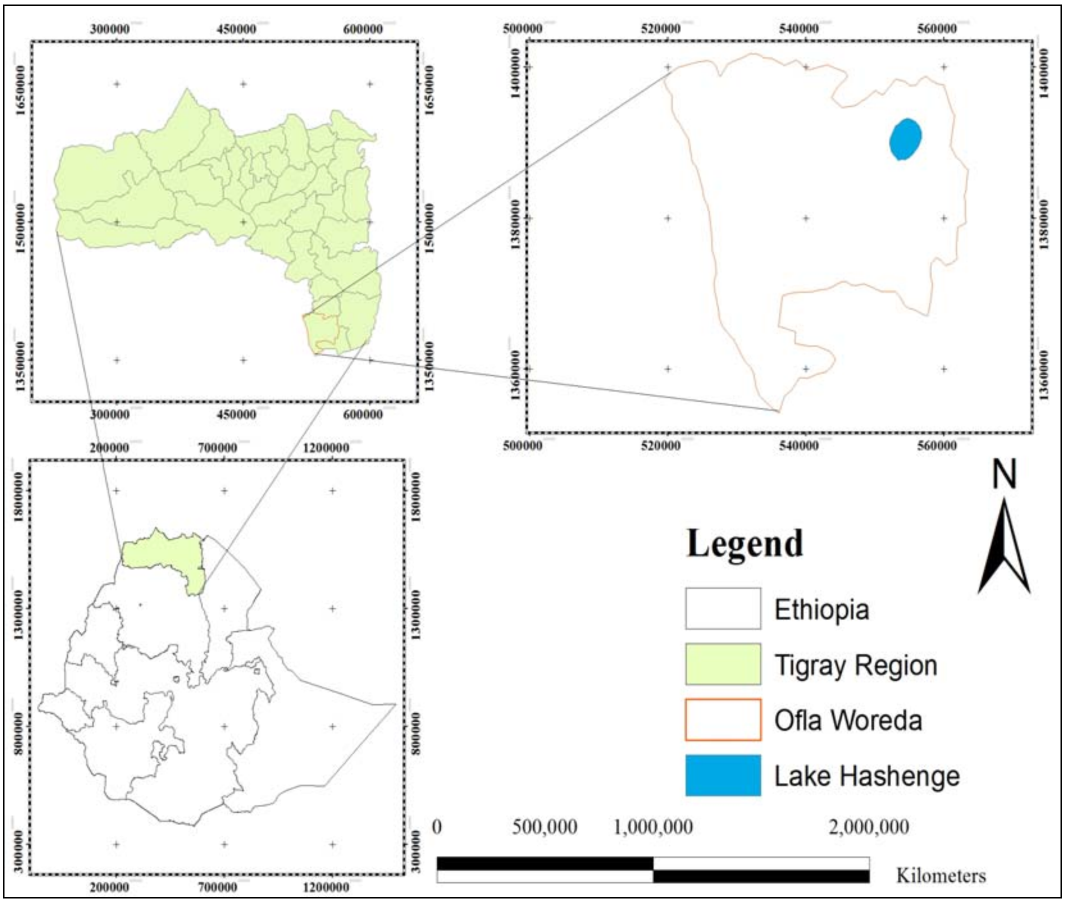

Figure 1: Location of the study area

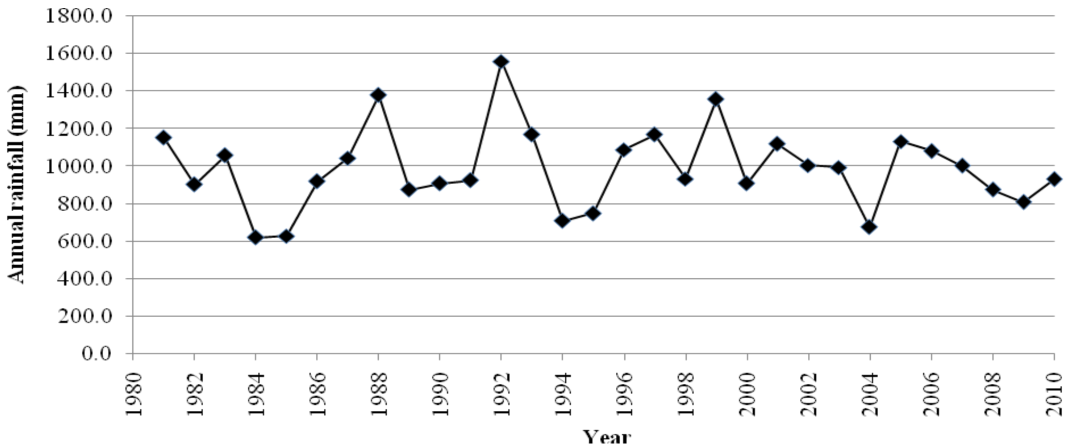

Figure 2: Annual rainfall distribution of the study area (1981-2010)

The land use of the study area includes cultivated land, forest land, closure area, grazing land, residential area and the lake (Figure 3). The catchment area is characterized by undulating surface having flat lands and mountainous chains. The mountains that surround the flat grazing land, cultivated land and lake area are characterized by gentle to very steep slopes with elevation ranging from 2,440 to 3,600 m above sea level.

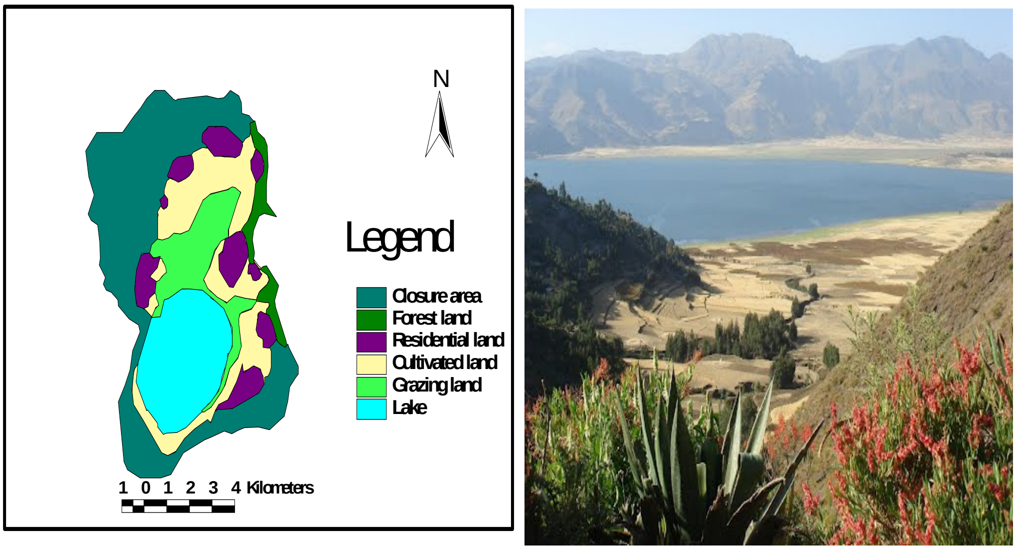

Figure 3: Land use map of the study area

The morphometric characteristics of Lake Hashenge are given in Table 1.

Table 1: Morphometric characteristics of Lake Hashenge and the catchment

No	Parameters	Value
1	Catchment area (including the lake (km^2)	80.8
2	Average slope of the catchment (%)	33.0
3	Slope of the main river (%)	10.5
4	Average sediment yield (ton $ha^{-1} year^{-1}$)	6.9
5	Lake area (km^2)	14.5
6	Lake perimeter (km)	14.7
7	Lake maximum depth (m)	20.0
8	Mean lake depth (m)	11.9
9	Lake altitude (m.a.s.l)	2440.0

2.2 Lake Water Balance

The lake water budget was computed using Equation 1 by measuring or estimating all of the lake's water gains (inflow) and losses (outflow) and measuring the corresponding change in the lake level over the same period.

ΔV_L = Inflow – Outflow

$$\Delta V_L = (V_P + V_{Ro} + V_Q + V_{Gi}) - (V_E + V_W + V_{GO}) \quad (1)$$

Where

ΔV_L = Change in lake water volume (m^3)
V_P = Direct precipitation on the lake (m^3)
V_{Ro} = Surface runoff from the catchment (m^3)
V_Q = Stream flow to the lake (m^3)
V_{Gi} = Groundwater inflow to the lake (m^3)
V_E = Evaporation from the lake (m^3)
V_W = Abstraction from the lake (m^3)
V_{GO} = Groundwater outflow from the lake (m^3)

Data collection of the water balance components of Lake Hashenge was made for 135 days in 2010 (November 19 to April 3). As a result, the water balance assessment was carried out for two scenarios, vis-à-vis, observation period and annual water balance.

2.2.1. Observation period water balance of the lake

2.2.2. Change in lake water volume (ΔV_L)

Four graduated steel bars were installed at four corners of the lake to measure the change in water level over the observation period (Figure 4) while the initial and final surface area of the lake was determined using Geographic Positioning System (GPS). The change in lake water volume was then calculated using Equation 2.

$$\Delta V_L = \Delta D_L * A_{Lav} \quad (2)$$

Where

ΔV_L = Change in lake water volume during the observation period (m^3)
ΔD_L = Change in lake water level during the observation period (m)
A_{Lav} = Average surface area of the lake during the observation period (m^2) [$(A_I+A_F)/2$]
A_I = Surface area of the lake at the beginning of the observation period (m^2)
A_F = Surface area of the lake at the end of the observation period (m^2)

Figure 4: Graduated steel bar installed to monitor the change in water level of the lake

2.2.3. Surface inflow into the lake

The surface inflow into the lake includes direct precipitation, runoff from the catchment and stream flow. Manual raingauge was installed in the area to measure the daily precipitation on the lake over the observation period and converted into the corresponding volume (V_P) using the average surface area of the lake.

The volume of runoff that enters into the lake from the surrounding catchment was computed by using runoff coefficient method (Equation 3).

$$V_{Ro} = C * P * A \quad (3)$$

Where:
V_{Ro} = Runoff volume (m^3)
P = Precipitation (m)
A = Area (m^2)
C = Weighted runoff coefficient

The daily flow of water into the lake by streams was measured using a nine inch throat width parshall flume (Figure 5). The upstream water level of the flume was measured every day and the corresponding discharge determined from the calibration curve. The daily discharge was then converted to the corresponding volume based on the time of flow. Finally, the daily volumes were summed up to get the total volume of stream inflow over the observation period (V_Q).

Figure 5: Measurement of stream flow using parshall flume

2.2.4. Surface outflow from the lake

The surface outflow from the lake includes evaporation and abstraction. The open water evaporation was estimated using Penman method (Shaw, 1994).

$$E_O = (\Delta / \gamma) H + Ea / (\Delta / \gamma + 1) \quad (4)$$

Where

E_O = Open water evaporation (mm/day)
H = The available heat
Δ/ γ = Weighting factor
Ea = Empirical value (mm/day)

The volume of evaporation loss from the lake over the observation period was then computed using Equation 5.

$$V_E = Eo * A_{Lav} \quad (5)$$

Where
V_E = Volume of evaporation loss from the lake during the observation period (m^3)
Eo = Depth of evaporation loss from the lake during the observation period (m)
A_{Lav} = Average surface area of the lake during the observation period (m^2)

The total volume of abstraction of water from the lake during the observation period was computed using Equation 6.

$$V_w = V_{irr} + V_{LS} + V_{HH} \quad (6)$$

Where
V_w = Total volume of abstraction from the lake during the observation period (m^3)
V_{irr} = Volume of irrigation abstraction during the observation period (m^3)
V_{LS} = Volume of livestock consumption during the observation period (m^3)
V_{HH} = Volume of household consumption during the observation period (m^3)

Some farmers in the area use motor pumps to withdraw water from the lake for irrigation. As a result, the numbers of pumps used for irrigation were primarily counted and their corresponding discharge determined using volumetric method. The total time of operation of irrigation of each pump during the observation period was then recorded and used to convert the discharge into corresponding volume used for irrigation (V_{irr}).

The number, type and age of livestock that consume water from the lake were counted once every week and the daily average number determined. Types and ages of livestock were randomly selected and provided with known volume of water in a plastic pan to determine the consumption rate. The daily livestock consumption was then calculated based on the average number of livestock and corresponding consumption rate. The daily values were finally summed up to get the total volume of livestock consumption during the observation period (V_{LS}).

Since the lake water is salty, the farmers use it for construction purpose only. There are five watering points for this purpose and the average daily abstraction for household purpose was determined by counting the number of known volume of plastic containers in each watering points at various times. The daily household withdrawals over the observation period were summed to determine the total volume (V_{HH}).

2.2.5. Groundwater inflow (VGi) and outflow (VGo)

Groundwater flow to or from the lake is often invoked to explain lake level changes that are not well understood on the basis of surface hydrology. Groundwater flow is the exception and is an important and largely overlooked component of water budgets because it is the most difficult to quantify as it cannot be measured directly. As a result, Equation 1 was rearranged as follows to indirectly determine the net groundwater flow.

$$\Delta G_w = (\Delta V_L + V_E + V_W) - (V_P + V_{Ro} + V_Q) \quad (7)$$

Where:

ΔG_w = Net groundwater inflow/outflow = $V_{Gi} - V_{Go}$

2.2.6. Annual water balance of the lake

The annual water balance of the lake was assessed mainly based on the long term annual rainfall, runoff and other meteorological data. However, abstractions and stream flows during the observation period were annualized to present the general overview of the inflow and outflow as there was no long term data for these parameters.

2.3 Bathymetric Survey

The bathymetric data was measured using a rope and GPS by classifying the lake into grids. A heavy metal was attached to one end of the graduated rope while the other end was tied to the side of the boat. The metal end was then released to the bottom of the lake at every grid coordinate and the corresponding depth recorded. The geographic location of the depth sampling points was recorded using Global Position System (GPS). The bathymetric map was finally prepared on the basis of these measurements.

2.4 Materials

The major materials used include parshall flume, evaporation pan, raingauge, GPS, graduated metal sticks, plastic pan, ruler, tape meter, watch, graduated rope, plastic bag, digital camera, topographic map of scale 1:50,000, aerial photograph and GIS software.

3. RESULTS AND DISCUSSION

3.1 Temporal Variation of the Surface Area of Lake Hashenge

The change in the surface area of the lake over the last century was mapped using various mechanisms. Primarily, the boundaries of the lake in 1888, 1936 and 1979 were delineated with the help of the elders of the area. In addition, the 1994 and 2010 border was delineated using topographic map and GPS respectively. To view change in area of the lake over time, the lake boundary of the five different years were overlapped (Figure 6) and the changes in area of the lake over time calculated using GIS software are presented in Table 2.

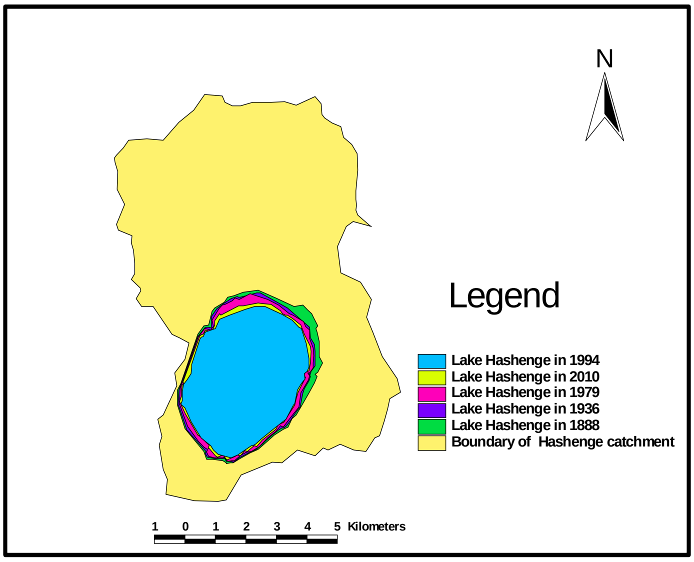

Figure 6: Overlapped maps of Lake Hashenge in different years

Table 2: Area of the Lake Hashenge in different years

No	Year	Time difference in year	Area m^2	Area difference m^2
1	1888		18,028,271	
2	1936	48	16,685,874	-1,342,397
3	1979	43	16,072,202	-613,672
4	1994	15	13,776,146	-2,296,056
5	2010	16	14,568,699	+792,553

3.2 Lake Water Balance

3.2.1. Observation period water balance of the lake

The main inflows during the observation period were direct precipitation and stream flows while the outflows include evaporation, livestock consumption, household consumption, irrigation and groundwater outflow.

3.2.2. Change in lake water volume (ΔV_L)

The total change in lake level during the observation period was -320 mm. The surface water area of the lake at the beginning and end of the observation period was 14,568,699 m^2 and 14,410,531 m^2 respectively. The change in volume of the lake was calculated using Equation 2 and found to be - 4.64 * 10^6 m^3.

3.2.3. Surface inflow into the lake

i. Volume of direct precipitation on the lake (V_P)

The total rainfall during the observation period was 100.7 mm. The total depth of rainfall was multiplied by the average surface area of the lake during the observation period and the corresponding volume of direct precipitation was found to be 1.46 * 10^6 m^3.

ii. Volume of runoff from the catchment (VRo)

There was no rainfall event that caused runoff from the catchment during the observation period. As a result, the contribution of runoff to the inflow was assumed to be zero.

iii. Stream flow to the lake (VQ)

Lake Hashenge has five streams that supply baseflow and the total volume of stream inflow measured by parshall flume was found to be 0.73 * 10^6 m^3.

3.2.4. Surface outflow from the lake

i. Volume of evaporation loss from the lake (VE)

The annual lake evaporation was 1301.1 mm and the amount of evaporation loss during the 135 observation days was 393.83 mm. The corresponding volume of water lost through evaporation during the observation period was calculated using Equation 5 and found to be 5.706 * 10^6 m^3.

ii. Volume of water abstraction from the lake (Vw)

As indicated in Chapter 2, abstraction from the lake constitutes irrigation, livestock and household consumption. The water withdrawn for irrigation, livestock and household purposes during the observation period was 7,581.3 m^3, 9,867.96 m^3 and 89.64 m^3 respectively. The total volume of abstraction (Vw) during the observation period was then calculated using Equation 6 and found to be 17,538.59 m^3.

3.2.5. Ground water inflow (V_{Gi}) and outflow (V_{Go})

With all the remaining water balance components of the lake measured or estimated, the net groundwater inflow or outflow (ΔGw) (V_{Gi} -V_{Go}) was estimated using Equation 7 and found to be -1.106*10^6 m^3. The negative sign indicates that groundwater outflow (V_{Go}) is 1.106 *10^6 m^3 greater than that of groundwater inflow (V_{Gi}) during the observation period.

3.2.6. Summary

Table 3 presents the summary of the water balance components of Lake Hashenge during the observation period.

Table 3: Observation period water balance summary of Lake Hashenge

General data				
Observation period				
Duration	19 November 2010 – 3 April 2011			
Number of days	135			
Surface area of the lake				
Initial (A_I) (m^2)	14,568,699			
Final (A_F) (m^2)	14,410,531			
Average (A_{Lav}) (m^2)	14,489,615			
Change in lake water				
Change in water level (mm)	- 320			
Change in volume (m^3)	- 4.64 * 10^6			
Water balance data				
Components	**Observation period water balance**		**Average daily water balance**	
	in 10^3 m^3	**in %**	**in 10^3 m^3/d**	**in mm/d**
Inflow	**2,190.00**	**100.0**	**16.22**	**1.12**
Direct precipitation on the lake	1,460.00	66.7	--	--
Runoff from the catchment	0.00	0.0	0.00	0.00
Stream flow	730.00	33.3	5.41	0.37
Outflow	**6,829.54**	**100.00**	**50.60**	**3.49**
Evaporation loss	5,706.00	83.55	42.27	2.92
Abstraction	17.54	0.26	0.13	0.01
Irrigation	*7.58*			
Livestock consumption	*9.87*			
Household consumption	*0.09*			
Net groundwater outflow	1,106.00	16.19	8.19	0.56

Similar to the rift valley lakes, Hashenge is also characterized by high amount of outflows during the dry season (Ayenew, 2004).

The inflow into the lake during the observation period was only from direct precipitation and stream flows. Out of the total inflow of 2.19 million m^3, 66.7 % was contributed by precipitation while the remaining 33.3 % was received from the five streams. The result generally indicates the importance of precipitation in maintaining the water balance of the lake. The outflow, on the other hand, was 6.83 million m^3 of which 99.74 % is a non-productive loss in the form of evaporation and groundwater outflow. The water lost from the lake in the form of evaporation and net groundwater outflow contribute about 83.55 % and 16.19 % respectively.

This is actually due to the large open lake surface area exposed for evaporation and the corresponding high lake perimeter through which water can infiltrate. The water withdrawn for productive purposes including irrigation, livestock and household consumption was only $17.54 * 10^3$ m^3, which is 0.26 % of the total outflow. As is the case in other parts of the East African rift valley lakes (Tenalem et al., 2007), there is no controlling mechanism of water abstraction from Lake Hashenge. However, the current state of abstraction has insignificant impact on the water balance. The cultural limitation on using the lake water for irrigation and its saline nature are the major contributors to the low level of irrigation abstraction in the area.

The change in volume of the lake during the observation period was - 4.64 million m^3, indicating larger amount of water going out than what comes in. Studies in other parts of Ethiopia have revealed the significance of climate change on lake water balance. Tenalem et al. (2007) indicated that 10% change in evaporation in Lake Awassa causes up to an average of 43 cm rise or fall in the simulated water level. The results of this study entirely agree with that of Tenalem (2007) with 267.4 mm of the 320 mm lake water level decrease over 135 days caused solely due to evaporation.

3.2.7. Annual water balance of the lake

The generalization results of the annual water balance assessment revealed an inflow and outflow respectively of 24.25 million m^3 and 21.89 million m^3, which means an annual surplus inflow of 2.36 million m^3 into the lake. This surplus inflow can be due to the integrated watershed management introduced in the catchment area, which may increase the stream discharges and groundwater inflow. The increase in the surface area of the lake witnessed in the last few years can be attributed to this fact (Table 2).

However, since this data is the result of generalization, it may not reflect the actual value. But, it has to be noted that the major water balance components such as direct precipitation, runoff and evaporation were not annualized but determined based on collected data. The ones' that were annualized such as abstraction, stream flow and groundwater outflow has less effect on the water balance. The annual water balance result may not, therefore, be far from the reality.

3.3 Bathymetric Survey

As indicated in the methodology, the bathymetric survey of the lake was carried out by a grid method using graduated rope and GPS for depth and coordinate measurement respectively. The bathymetric map of the lake was made at two meter contour interval and is given in Figure 7. The map provides an easy and clear visual understanding of the lake cross-section for every body's benefit. This map was also used for the surface area and volume computations at various depths.

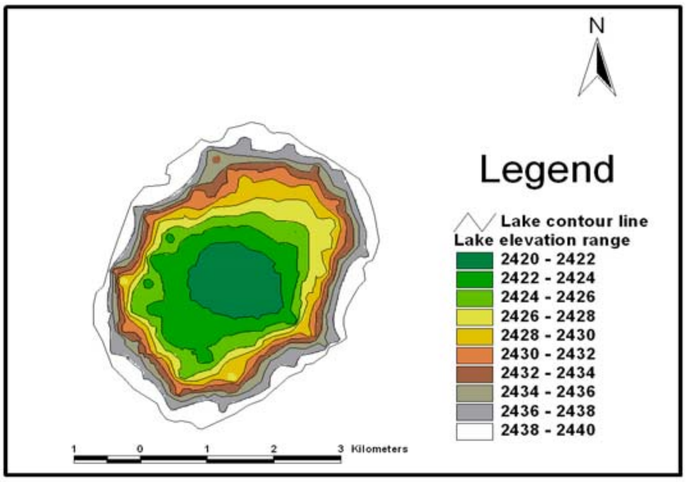

Figure 7: Bathymetric and contour map of Lake Hashenge

The maximum depth of the lake during the survey reaches 20 m (Lake Floor) with 154,965,283.17 m^3 volume. According to Garg (2005), updating the elevation - area - capacity curve of reservoirs greatly helps in planning and executing suitable remedial measures for controlling sedimentation in order to prolong the life of the reservoir and its benefits. Moreover, the amount of water supplied can easily be decided and determined by corresponding reservoir capacity from the elevation-area-capacity curves (Eyasu, 2005). The elevation - area - capacity relationship of Lake Hashenge can, therefore, help to know the surface area and volume of the lake by measuring a unit of depth. Figure 8 presents the computed surface area and volume of the lake at 2 m interval. For instance, in its present day condition, a 2 m decrease in depth shrinks the lake by 1.45 km^2 or the first outer surface in Figure 7 (area between 2,438 and 2,440 m elevation) could be lost which is 10% of the current lake surface area.

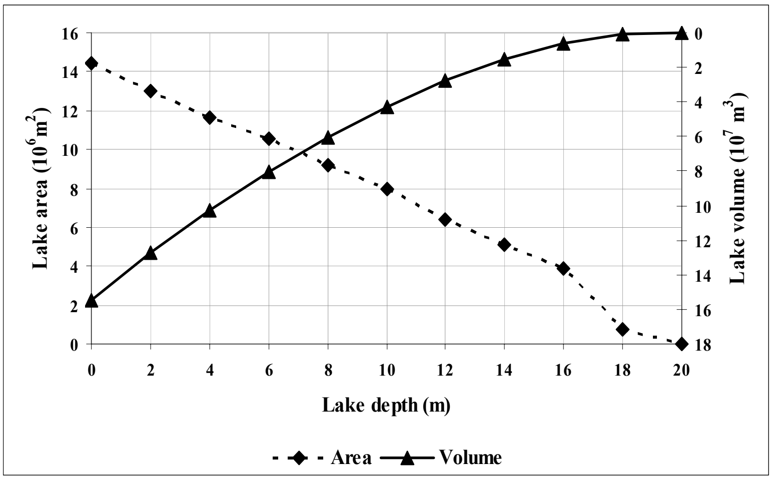

Figure 8: Bathymetric and contour map of Lake Hashenge

4. CONCLUSION AND RECOMMENDATIONS

The most important components of water balance of the lake during observation period were direct precipitation (66.7 %) and stream flow (33.3 %) as inflow and evaporation (83.55 %) and groundwater outflow (16.19 %) as outflow. Since the outflow was by far higher than the inflows, the lake showed a decrease in level of 0.32 m over the observation period. Based on the elevation-area-capacity relationship developed by bathymetric method, a 2 m decrease in depth shrinks the lake by 1.45 km^2 which is 10 % of the current lake surface area.

The sustainability of Lake Hashenge is largely related to the risk of sedimentation and the amount of inflow, both of which would require proper watershed management. The on-going integrated watershed management should be continued and its performance needs to be evaluated.

This study is the first initiative of its kind. This initial attempt should, therefore, be strengthened by generating additional and reliable data that could support informed decision-making. Monitoring of water balance components over the whole year and updating of the elevation-area-capacity curve and lake water budgeting should be carried out regularly. In addition, accurate quantification of groundwater inflow to and outflow from the lake will improve the water balance estimation.

5. ACKNOWLEDGEMENT

Many thanks and gratitude goes to the Research and Community Services Council of the College of Dryland Agriculture and Natural Resources and NORAD III Project of Mekelle University for providing the fund for undertaking this research. The Ethiopian Meteorological Services Agency and Ofla Wereda Agriculture and Rural Development office are also acknowledged for providing relevant meteorological and other secondary data on Lake Hashenge. Last but not least, we would like to forward our warm appreciation to Ato Amare Tesfamariam, Fish Production investor at Lake Hashenge, for providing boat for the bathymetry survey freely.

6. REFERENCES

1. Ayenew, T., 1998, "T*he Hydrogeological System of the Lake District Basin. Central Main Ethiopian Rift*", PhD Thesis. Free University of Amsterdam. Amsterdam, the Netherlands. 259 pp.
2. Ayenew, T**.,** 2002, "Recent Changes in the Level of Lake Abiyata, Central Main Ethiopian Rift", Hydrological Sciences. 47(3):493-503.
3. Ayenew, T., 2004, "Environmental Implications of Changes in the Levels of Lakes in the Ethiopian Rift since 1970", Regional Environmental Changes. 4:192-204.
4. Becht, R., and Harper, D., 2002, "Towards an Understanding of Human Impact up on the Hydrology of Lake Naivasha".
5. Eyasu Y., 2005, "*Development and Management of Irrigated Lands in Tigray*", Ethiopia. PhD Thesis. UNESCO-IHE Institute for Water Education. Delft, the Netherlands.
6. Garg, S.K., 2005, "Hydrology and Water Resources Engineering".
7. Halcrow, 1989, "*Master plan For the Development of Surface Water Resources in Ten Awash Basin*", vol. 6. Ministry of Water Resources. Addis Ababa, Ethiopia.
8. Makin, M.J., Kingham, T.J., Waddams, A.E., Birchall C.J. and Eavis, B.W., 1976, "*Prospects for Irrigation Development around Lake Ziway*, *Ethiopia*". Land Resources Study Division, Ministry of Overseas Development. Tolworth, United K.ingdom.
9. Shaw, E.M., 1994, "*Hydrology in Practice*", Chapman and Hall. London, UK.
10. Tenalem, A., Robert, B., Arno van, L., Yemane, G., Dagnachew L. and Japheth, O., 2007. "Hydrodynamics of Topographically Closed Lakes in the Ethio – Kenyan Rift: The case of Lakes Awassa and Naivasha".
11. OWARD, 2010, "*Annual report*", Ofla Wereda Agriculture and Rural Development office. Korem, Tigray, Ethiopia.

7. AUTHORS BIOGRAPHY

Dr. Eyasu Yazew, Dr. Girmay GebreSamueal and Mr. Samuale Tesfaye are lecturers and researchers in the Department of Land Resources Management and Environmental Protection at Mekelle University. Mr. Shimbahri Mesfin is a graduate of the Tropical Land Resources Management MSc program of the Mekelle University. Dr. Eyasu is an active member of the Nile Basin Capacity Building Network for River Engineering.